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Quaternary Newsletter



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QUATERNARY NEWSLETTER

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Instructions to authors

Quaternary Newsletter is issued in February, June and October. Articles, reviews, notices of forthcoming meetings, news of personal and joint research projects etc. are invited and should be sent to the Editor. Closing dates for submission of copy (news, notices, reports etc.) for the relevant numbers are 1st January, 1st May and 1st September. These dates will be strictly adhered to in order to expedite publication. **Articles must be submitted at least 6 weeks before these dates in order to be reviewed and revised in time for the next issue of QN, otherwise they may appear in a subsequent issue.**

Suggested word limits are as follows: obituaries (2000 words); articles (3000 words); reports on meetings (2000 words); reports on QRA grants (500 words); reviews (1000 words); letters to the Editor (500 words); abstracts (500 words). Authors submitting work as Word documents that include figures must send separate copies of the figures in .eps or .jpg format. In case of the latter, a minimum resolution of 300 dpi is required for accurate reproduction. Quaternary Research Fund and New Researchers Award Scheme reports should limit themselves to describing the results and significance of the actual research funded by QRA grants. The suggested format for these reports is as follows: (1) background and rationale (including a summary of how the grant facilitated the research), (2) results, (3) significance, (4) acknowledgments (if applicable). The reports should not (1) detail the aims and objectives of affiliated and larger projects (e.g. PhD topics), (2) outline future research and (3) cite lengthy reference lists. No more than one figure per report is necessary. Recipients of awards who have written reports are encouraged to submit full-length articles on related or larger research projects.

NB: Detailed guidelines on the formatting of contributions are now available via the QRA webpage and from the editor, including an EndNote style file to help with the formatting of bibliographies for submissions to *QN*.

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COVER PHOTOGRAPH

View of lake Disko 2 during summer fieldwork in August 2013 (photograph by Mark Stevenson; see related ¹⁴CHRONO Award report by Stevenson in this issue).

CORRESPONDENCE

A TALUS ROCK GLACIER ON EXMOOR?

A COMMENT ON THE ARTICLE BY BOREHAM AND ROLFE (2014)

David Jarman, Peter Wilson and Stephan Harrison

We are naturally gratified that our paper refuting the small and scattered population of proposed ‘relict rock glaciers’ in Britain (Jarman *et al.*, 2013) has been found ‘rigorous’ by Steve Boreham and Christopher Rolfe in QN 134 (October 2014). Indeed, the 5-year process of consummating it felt pretty rigorous, not least obtaining agreement from almost all the proponents of that population to reinterpretation of their sites. But not rigorous enough, perhaps, as the ‘Whack-a-mole’ principle pops up to demonstrate. In fairness however, the recency of our paper may have prevented it being taken on board when the work programme for this new candidate ‘talus rock glacier’ site on Exmoor was devised (Boreham and Rolfe, 2014).

Nor do we dismiss this site as too trivial to nail, since those citing papers in favour of the existence of such relict rock glaciers may not always ascertain their actual scale and context. More importantly, in marginal locations (topographically and climatically) such as this, it is necessarily very small features which may be crucial in detecting outermost limits of Quaternary activities (e.g. Evans *et al.*, 2012, on Dartmoor).

We have to suggest however that this is a somewhat implausible location for a talus rock glacier (Figure 1). The site is open moorland, a slight interfluvium between two shallow stream courses, sloping gently north from 400 m to 300 m OD over 1250 m. Beyond the western stream, a 50 m-high bank is unlikely to have provided the exceptionally abundant supply of coarse debris required to initiate a rock glacier (such as a rock wall or debris slide). Nor is the narrow fluvially-incised valleyhead likely to have generated such material. The boulder field (their Figure 2A) is discernible on GoogleEarth but is not unusual, and probably too thin to be such an exceptional supplier.

The two main ridges (their transect A) are just visible on flat-light GoogleEarth, as steps on a local slight steepening. They are very short (~200 m) and barely arcuate, more contour-parallel (as the authors observe). They might be solifluction terraces. The more numerous micro-ridge arrays (their Transect

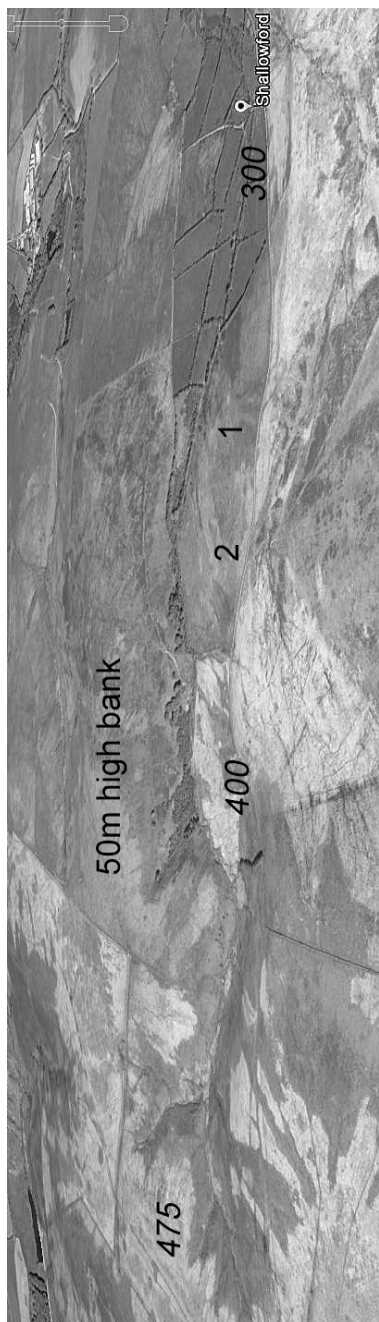


Figure 1. Low-angle oblique image of Shallowford site context looking west © Google Earth 2014. Approximate locations of their transects 1 and 2 are indicated; the two main ridges are just visible at 4 o'clock from '1'. Elevations in metres.

2) are even shorter and invisible on GoogleEarth. On the DEM (their Figure 2B), they occur widely and might be anthropogenic.

The features presented here do not resemble any of those examined in our review of the 28 supposed British ‘rock glaciers’, whether as landforms or in topographic context. A new style or subset of ‘talus rock glacier’ is thus being proposed here, in a moorland rather than montane context. It is a basic test in labelling any landform that, if one example exists, there should be others in the vicinity, unless the circumstances support a *sui generis* interpretation; this is clearly important if climatic inferences are to be drawn. Since this is an unexceptional location, it should be one of a good number. The authors appear not to have identified any others on their air photo and DEM imagery of Exmoor. More importantly, the extensive studies of periglacial phenomena on Dartmoor (fully summarised in Campbell et al., 1998) allude to a wide spectrum of standard periglacial landforms but make no mention of any kind of rock glacier. Tellingly, the abundant block supply there tends to form downslope runs and stripes (clitter), rather than horizontal or lobate forms. Nor, on Exmoor, has a 2-3 m thickness of coarse debris in the (exceptional) Valley of Rocks spawned any such features (albeit nearer sea level, but still heavily periglacialised) (Campbell, 1998).

The authors freely admit that this is a fall-back interpretation, after suspicions of moraines had to be dismissed; but they only cite one other recent reference on rock glaciers – in Greece. Whatever periglacial origins may exist for these Exmoor features, they cannot by definition be ‘protalus ramparts or the protalus lobes of a talus rock glacier’ as the authors propose, since they are not located beneath talus slopes.

We note that the authors’ title ends with a “?” – as did ours. Our seeking to whack down this little mole should therefore not be too painful. Indeed their article can be welcomed as illustrating the challenges of micro-geomorphology with new analytic techniques – and as the first response to our own invitation to put forward ‘relict rock glacier’ candidates which might pass the simple categorisational tests we presented.

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Editor's note: The authors of the original article chose not to respond to this comment.

JAMES CROLL AWARD

CITATION FOR THE JAMES CROLL MEDAL

The James Croll Medal is the highest award of the QRA and is named in honour of James Croll (1821-1890). Croll is most closely associated with fundamental work on the astronomical theory of the ice ages, but he also made seminal contributions on the glacial geology of Scotland, on the mechanisms that drive ocean circulation and the impact of that circulation on recent climate, on tidal theory and the rotation of the Earth. These are all major issues that occupy Quaternary scientists to this day. The Medal is normally awarded to a member of the QRA who has made an outstanding contribution to the field of Quaternary science, and whose work has also had a significant international impact. The QRA is delighted to announce that the 2014 James Croll Medal has been awarded to Professor Phil Gibbard, Department of Geography, University of Cambridge.

Phil has made an outstanding contribution to Quaternary science through his original research spanning Britain, North and South America, Europe and the Far East. He has extremely broad-ranging interests, with research extending from glacial, periglacial and interglacial stratigraphy, through the investigation of fluvial sediments and to the analysis of shallow marine and coastal deposits, and the application of palynology to reconstruct Pleistocene palaeoenvironments. He first considered the interactions between glaciation, rivers and the sea during his thesis research (supervised by Professor Richard G. West, University of Cambridge), which investigated the past course of the River Thames and considered its diversion from East Anglia to flowing through London. Through his background as a geologist (BSc Special Honours Geology, University of Sheffield), Phil's application of stratigraphical principles and practices to Pleistocene and late Pliocene sequences have defined some of his most important contributions to Quaternary science (e.g. Gibbard, 1988, 1994; Gibbard and Lautridou, 2003; Gibbard *et al.*, 1991). He has produced more than 250 publications (see <http://www.qpg.geog.cam.ac.uk/people/gibbard/>), including compiling an atlas on global Quaternary glaciation limits (Ehlers and Gibbard, 2004a,b,c) which included 250 contributors across 46 countries, and which is now in its second edition (Ehlers *et al.*, 2011). His interest in stratigraphical principles is also reflected in his contributions to debates on defining various sub-divisions of the geological timescale, with a focus on the Quaternary (e.g. Gibbard and Pillans, 2008; Gibbard *et al.*, 2004; 2010). Phil has edited the *Journal of Quaternary Science* (1985-1999), and been a member of Editorial Boards for *Journal of Quaternary Science* (1985-2007), *Netherlands Journal of Geosciences*, *Boreas*, *Geoheritage*, *Alpine*

and Mediterranean Geology (2012-), *Eiszeitalter und Gegenwart* (2012-), *Quaternaire*, *Quaternary International* (2013-), *Geological Magazine* (1996-2006), *Geological Quarterly* (2003-2009), *Bulletin de la Société géologique de France* (2004-2008), *Journal of the Geological Society* (Advisory Editor, 2001-2008). His national and international reputation is further highlighted by the award of the Geological Society of London Lyell Fund, an Honorary Doctorate from the University of Helsinki, and the André Dumont Medal from Geological Belgica.

A major significant impact by Phil comes from his work as Chair of the Subcommission on Quaternary Stratigraphy (SQS) of the International Commission on Stratigraphy (ICS). When the International Geological Time Scale 2004 was published, the Quaternary had been excised from the stratigraphic record, and replaced by the Neogene system which had been extended to the present day. Phil refused to accept this radical change nor an alternative argument for re-instating the Quaternary at a lower rank, and as Chair of the SQS he waged a tireless campaign to have the Quaternary re-instated as a stratigraphic unit of full system/period rank. The outcome was a series of votes within the ICS and IUGS and the formal ratification by the IUGS of the Quaternary as a system/period and the Pleistocene as a series/epoch with a base at 2.58Ma. Without Phil's dogged determination to safeguard the Quaternary, it could indeed have gone the way of the Tertiary and disappeared from the Geological Time Scale.

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For a full publication list see: <http://www.qpg.geog.cam.ac.uk/people/gibbard/>

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Pete Coxon
President of the QRA
January 2015

LEWIS PENNY AWARD

CITATION FOR THE THE LEWIS PENNY MEDAL

The QRA is delighted to announce that the 2014 Lewis Penny Medal has been awarded to Dr Bethan Davies, Royal Holloway University of London, in recognition of her very significant contributions to advancing understanding of the British Middle Pleistocene record and the ice sheet history and dynamics of the last British Ice Sheet. The Lewis Penny Medal is awarded in memory of Lewis and his contributions to Quaternary science and support of the QRA, and made possible by the generous donation of Lewis's former students, friends and colleagues. The prize is awarded to a young or new research worker who has made a significant contribution to the Quaternary stratigraphy of the British Isles and its maritime environment (including adjacent areas of continental Europe with relevance to the British Isles).

Bethan Davies

A key strength of Bethan Davies' research is her approach in applying multiple techniques to the investigation of Quaternary and glacial history, including the British Isles but also encompassing research on Antarctic and Patagonian glaciation. The methods that she has employed include sedimentology, micromorphology, geochemical tracing, lithological analysis, heavy mineral analysis, AAR, OSL, U-series, macro-fossil analysis (molluscs) and palynomorphs. Furthermore, she has adopted this multi-proxy approach to examine, challenge, and re-interpret both the Middle Pleistocene glacial and environmental record in the British Isles, and the history and dynamics of ice-sheet history in the North East of England.

Bethan is a graduate of the University of Nottingham (BSc. Geography, 2004), Royal Holloway University of London (MSc. Quaternary Science, 2005) and Durham University (PhD Geography: '*British and Fennoscandian ice sheet interactions during the Quaternary*', 2009). Her initial work on the coast of North-east England led to a step-change in our knowledge of Middle Pleistocene glacial-interglacial stratigraphy. Bethan examined sequences



at Warren House Gill and Shippersea Bay (Easington Raised Beach), and showed that the famous ‘Scandinavian Drift’ of Warren House Gill is actually glaciomarine in origin and that the sediments are largely derived from the British–Irish Ice Sheet (BIIS) rather than Fennoscandia (Davies *et al.*, 2012b). She also re-interpreted and dated a ‘loess’ reported by Trechmann (1915) as a temperate-stage estuarine deposit, and revised the age of the Easington raised beach to Marine Isotope Stage 7 (Davies *et al.*, 2009). Bethan’s research has also advanced knowledge of ice-sheet history in North-east England during the Last Glacial Maximum. From the Durham coast, she re-assessed evidence for independent ice lobes (Davies *et al.*, 2012a), and investigated the genesis and provenance glacial sediments associated with the Tyne Gap ice stream and the North Sea lobe (Davies *et al.*, 2009). Importantly, she attempted one of the first onshore/offshore correlations of glacial stratigraphy in the central North Sea and provided new insights into the process origin of many of the offshore glacial formations (Davies *et al.*, 2011).

More recently, Bethan has also developed research expertise in Antarctic and Patagonian glaciation, including through a SCAR (Scientific Committee for Antarctic Research) fellowship at Victoria University of Wellington, New Zealand, and Postdoctoral research positions at British Antarctic Survey and the Universities of Aberystwyth and Reading. She has investigated Antarctic Peninsula glaciation during the Cenozoic (Davies *et al.*, 2012d; Ó Cofaigh *et al.*, 2014), including assessment of recent dynamic changes to glaciers there and in Patagonia (Davies *et al.*, 2012c; Davies and Glasser, 2012) and adopting numerical modelling approaches (Davies *et al.*, 2014).

Bethan has supported QRA activities through lead-authoring/co-editing the new QRA guide on ‘The Quaternary of Northumberland, Durham and Yorkshire’ (Davies *et al.*, 2013) and she led the associated fieldtrip. She also co-organised and led the 2009 Glacial Landscapes Working Group annual meeting on the glacial history of the Durham and Yorkshire coast. Bethan has increased the visibility of Quaternary science through founding of the website www.AntarcticGlaciers.org, which delivers peer-reviewed science to the general public, A-Level and undergraduate students (supported by the QRA Outreach Fund and SCAR).

In summary, as an early career researcher Bethan has already demonstrated an exceptional and wide-ranging ability as a Quaternary scientist, given a track record of excellent research on past and present ice sheets and glacier dynamics. The QRA is delighted to recognise these achievements through the award of the Lewis Penny Medal.

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GLACIAL GEOLOGY IN NE ENGLAND

Bethan Davies

Introduction

I'd like to thank the QRA for bestowing me the honour of the Lewis Penny Medal. It is a pleasure to have my research recognised in this way, and to join the list of esteemed colleagues who have previously been awarded this medal. Most research, especially that in the field of Quaternary Science, is collaborative, and this Medal reflects this successful endeavour.

Quaternary sediments crop out all along eastern England, from Northumberland through Yorkshire to Norfolk. These sediments have been a focus for Quaternary lithostratigraphy for well over a hundred years (Young and Bird, 1822, Reid and Woodward, 1882, Trechmann, 1915), with the Boulders Committee in NE England doing a sterling job of mapping and identifying ice-flow pathways from the distribution of glacial erratics (Woolacott and Trechmann, 1913, Harmer, 1928). Much of the early work that developed our understanding of the Dimlington Stadial and previous incursions of an ice sheet over Britain stems from the work of John Catt and Lewis Penny himself, working on glacial sediments in Yorkshire in the 1960s and 1970s (Catt and Penny, 1966, Penny and Catt, 1967, Penny *et al.*, 1969, Madgett and Catt, 1978, Catt and Digby, 1988, Catt, 2007).

Recent research in NE England

Over the last 15 years, there has been a re-growth of interest in the glacial sediments in eastern England, with the development of quantitative provenance tools that have improved our understanding of ice-flow pathways (Lee, 2001, Lee *et al.*, 2002), and the development of micromorphology as a tool to understand processes of sediment deposition (van der Meer, 1993, 1997; Menzies, 2000, 2012; Phillips *et al.*, 2011; Phillips and Lee, 2012; Phillips *et al.*, 2013). These techniques have led a surge in interest, with the extent of Scandinavian-sourced ice in Britain during the Late Pleistocene increasingly being questioned. In Co. Durham, teams of researchers led by David Roberts, David Evans, Colm Ó Cofaigh and David Bridgland have been reinvestigating some of these deposits, leading to new interpretations of the lithostratigraphy, new stratigraphic correlations and a new understanding of ice stream interactions in eastern England and the North Sea Basin during the Middle (Davies *et al.*, 2009a, 2012b) and Late Pleistocene (Davies *et al.*, 2009b; Boston *et al.*, 2010; Evans and Thomson, 2010; Livingstone *et al.*, 2010; Davies *et al.*, 2011, 2012a, 2013; Livingstone *et al.*, 2012; Roberts *et al.*, 2013).

My own research in this area has highlighted the Scottish provenance and glaciomarine genesis of the Middle Pleistocene 'Scandinavian Drift' of Warren House Gill (Davies *et al.*, 2012b). Working with Ian Candy, Stephen Pawley, Kirsty Penkman and Beatrice Demarchi, I was able to date sediments lithostratigraphically above this 'Scandinavian Drift' (now the Ash Gill Member of the Warren House Formation), indicating that this sediment pre-dated MIS 6, casting further doubt on the likelihood of incursions of Scandinavian ice into Britain during the Pleistocene (Davies *et al.*, 2009a, 2012b).

Detailed provenance analysis allowed us to differentiate different stratigraphic units relating to the glaciation of the region during the LGM, identifying sediments from the Tyne Gap and Midland Valley of Scotland, associated with the Tyne Gap Ice Stream, and a later episode relating to the flow of the North Sea Lobe over the region (Davies *et al.*, 2009b, 2012a). This renewed understanding of ice-sheet dynamics, processes and provenance allowed us to revise regional lithostratigraphic correlations. By applying these techniques to boreholes from the North Sea Basin, I was able to attempt one of the first onshore-offshore correlations and to provide some of the first insights into the provenance of some of the key sedimentary formations in the North Sea (Davies *et al.*, 2011).

A key part of this research was the use of multiproxy lithostratigraphical techniques to constrain provenance. This included heavy mineral analysis, clast lithological analysis and till geochemistry. By taking a quantitative, statistical approach, similar to that pioneered by Jon Lee (Lee, 2001, Lee *et al.*, 2002), I was able to confidently relate different stratigraphic units in NE England and the North Sea (Davies *et al.*, 2009b, 2011, 2012a, 2013; Davies, in press). A process-based approach, using macro- and micro-scale sedimentology and facies architecture mapping ensured the robust interpretation of processes at the ice-bed interface, yielding insights into ice dynamics.

New developments

Developments in remote sensing and geomorphological mapping using satellite images and digital elevation models (especially NEXTmap) has revolutionised our understanding of ice-flow pathways. Geographic information systems have enabled us to compile huge datasets of geomorphic features, many of which have been made publically accessible to further glaciological research (Clark *et al.*, 2004, 2012; Evans *et al.*, 2005; Livingstone *et al.*, 2008, 2010, 2012; Greenwood and Clark, 2009; Hughes *et al.*, 2010, 2014).

In the North Sea Basin, the growth in availability of bathymetric data from the North Sea Basin in recent years has highlighted this region as a zone of complex ice-sheet interactions, with ice streams extending to the continental shelf (Graham *et al.*, 2007, 2009). The identification of moraines on the outer

continental shelf (Bradwell *et al.*, 2008) changed our understanding of the Last Glacial Maximum and highlighted the importance of understanding the North Sea Basin as a zone of interactions between the Fennoscandian Ice Sheet and the British Ice Sheet. Furthermore, as concerns grow regarding the stability of the marine West Antarctic Ice Sheet under a warming world (Joughin *et al.*, 2014; Mouginot *et al.*, 2014; Rignot *et al.*, 2014), we increasingly look to the North Sea Basin as an analogue for understanding processes of marine ice sheet instability and potential rates of collapse. The advent of wind farming in the North Sea Basin has resulted in a plethora of new data and several PhD projects have been launched here over recent years. In combination with large projects such as GLANAM and BRITICE-CHRONO, we can expect a vastly improved understanding of ice stream dynamics, ice limits and rates of recession in the North Sea Basin in coming years.

The advent of new dating techniques, in particular cosmogenic nuclide dating, has enabled researchers to better constrain rates of ice stream recession and ice-sheet thinning (Clark *et al.*, 2009; Fabel *et al.*, 2012; Glasser *et al.*, 2012). This technique will be fully utilised by the BRITICE-CHRONO project and by myself and colleagues working on dating the timing of ice-stream recession in northern England (Livingstone *et al.*, in review).

Future research

Despite over a century of research, our interest in the eastern sector of the British-Irish Ice Sheet is as keen and as important as ever. New developments in our understanding, new techniques and research tools, new focus on processes and new datasets are driving our efforts forward. The recent excellent QRA Annual Discussion Meeting (“The Quaternary Geology of the North Sea basin and adjacent areas”) highlighted how new 2D and 3D seismic data, new boreholes and multibeam swath bathymetry are opening up this major sedimentary archive. Over the next 5-10 years, we can expect to gain an understanding of ice limits throughout the Pleistocene, especially including the LGM. We hope to understand timing and rates of ice-sheet recession through the last glacial-interglacial transition, and to understand the thresholds that caused non-linear ice-sheet recession.

Major initiatives targeted at understanding the onshore record of ice-stream recession and ice-sheet thinning will use multiproxy chronostratigraphical techniques such as cosmogenic isotope dating, radiocarbon dating and optically-stimulated luminescence. This will build on published databases of ages (Hughes *et al.*, 2011; Clark *et al.*, 2012) to develop one of the World’s best frameworks for understanding ice dynamics through the last glacial cycle.

Interest in Middle Pleistocene ice dynamics continues to grow, with new datasets available in the North Sea Basin and with new tools to apply to

onshore sections. Understanding the interactions between the Fennoscandian Ice Sheet and British Ice Sheet, and the extent and timings of Fennoscandian ice incursions onto the British mainland, remains a research priority.

The combination of geological field data with numerical modelling offers an exciting opportunity to test geologically derived hypotheses and to relate ice sheet dynamics, including shifting ice divides, readvances and ice stream advances and recession, to climate. This has already been applied successfully in Britain (Evans *et al.*, 2009; Hubbard *et al.*, 2009; Evans *et al.*, 2012). The new generation of coupled ice-sheet models, constrained by the wealth of geological data now available, will be able to explicitly link complex ice-sheet dynamics to records of palaeo sea surface and air temperatures, in a way that is currently being attempted in Antarctica (Golledge *et al.*, 2012, 2014).

Acknowledgements

I hope the above summary shows how my research follows a long tradition of study on the glacial sediments of eastern England, and how it is sustained and developed under collaborative research. I am fortunate to always have been part of a stimulating research environment, whether at Royal Holloway, Durham University or Aberystwyth University. I am indebted to many colleagues over the years for stimulating and inspiring research discussions, many of which occurred on QRA field trips or other meetings. I am indebted in particular to Professor Jim Rose, who was an inspiration to me early in my career whilst undertaking the MSc in Quaternary Science at Royal Holloway, and who awakened an interest in British Ice Sheet dynamics. Dr Jon Lee was also an early inspiration, allowing me to participate in the BGS mapping programme during my MSc dissertation. I am indebted to Dr David Roberts, Professor David Bridgland and Professor Colm Ó Cofaigh from Durham University, who supervised my PhD research on the British Ice Sheet at Durham University. They remain great mentors, colleagues and role models and will always be in inspiration to me. I have been fortunate to work with Professor Neil Glasser and Professor Mike Hambrey at Aberystwyth University, who are excellent researchers and I was privileged to learn from them. I have also benefited from the expertise and generosity of many other colleagues working on the last British ice sheet over the years, including Dr Stephen Livingstone (Sheffield), Dr Clare Boston (Portsmouth), Dr Nicholas Golledge (Wellington), Professor David Evans (Durham), Dr Rob Westaway (Glasgow), Professor Chris Clark (Sheffield), Dr Lynda Yorke (Bangor), Dr Kirsty Penkman and Dr Beatrice Demarchi (York), Dr Tom White (Oxford), and many others who contributed to discussions at meetings and conferences. My thanks and warm wishes are extended to them all.

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HONORARY MEMBERS

Colin Ballantyne

Colin Ballantyne first developed his lifelong interest in Quaternary science and geomorphology at the University of Glasgow under the tutelage of the late Rob Price. Attainment of a First Class Honours degree enabled him, with Price's encouragement, to undertake an MSc degree at McMaster University in Canada, where he joined a team led by Brian McCann studying high arctic hydrology and fluvial processes on Ellesmere Island. Two long field seasons in the high arctic stimulated his enduring interest in periglacial environments and on returning to Scotland to undertake his PhD under the formidable supervision of Brian Sissons he chose to study the periglacial processes and landforms on mountains in NW Scotland. In January 1980



he was appointed lecturer in Geography at the University of St Andrews, subsequently promoted to Senior Lecturer in Geography and Geology in 1987, and appointed Professor in Physical Geography in 1994. Despite being based at St Andrews throughout his career, he has also been a visiting Lecturer at UNIS on Svalbard since 2000 and twice an Erskine Fellow at the University of Canterbury in New Zealand, where he teaches summer schools 'to get away from the ghastly Scottish winter'.

Three main research interests have dominated a research career that spans 40 years. Throughout that period he has contributed extensively to the literature on periglacial landforms and processes and has published widely-cited papers on such diverse phenomena as blockfields, protalus ramparts, ploughing boulders and plateau-top aeolian sand deposits. His work on periglacial phenomena on Scottish mountains led to his collaboration with Charles Harris in writing *The Periglaciation of Great Britain* (Cambridge University Press, 1994), which set the agenda for periglacial research in the British Isles for the next two decades. A second major interest has been in the reconstruction of former glaciers and their palaeoclimatic implications, particularly with regard to glaciers that formed during the Younger Dryas period in Scotland, work that included singlehanded reconstruction of former glacier limits on all major Hebridean islands between Orkney and Arran. A combination of his periglacial expertise with interest in Late Pleistocene glaciation led, perhaps inevitably, to research on the dimensions of

the last British Irish Ice Sheet, and in particular the possibility that the former ice sheet surface might be represented by trimlines that mark the upper limit of glacial erosion. Although initial research based on trimline mapping and analysis of clay mineralogy (together with the earliest ^{10}Be exposure ages reported in the British Isles) appeared promising, this ultimately proved a false dawn; conflicting evidence accumulated and by 2005 Ballantyne and his co-workers had accepted that trimlines represent englacial pressure thermal boundaries within a former ice sheet that overtopped all mountains in Britain and Ireland. This alternative model was elegantly demonstrated in a paper on the exposure age of high-level erratics by Ballantyne and Derek Fabel in 2012.

Ballantyne's international reputation was greatly augmented by the publication of a single long review paper in *Quaternary Science Reviews* in 2002. Entitled simply *Paraglacial Geomorphology*, this paper amassed a vast body of evidence to demonstrate that the trajectory of Holocene landscape change in formerly glaciated environments has been modified and often dominated by the influence of the preceding glacial episode, and encapsulated paraglacial landscape change in terms of the reworking of non-renewable sediment stores over timescales ranging from decades to millennia. This paper and its associated concepts 'went viral'; the paper has received over 500 citations and spawned a remarkable body of work that employed Ballantyne's ideas (sometimes over-enthusiastically) to evolve a paradigm of paraglacial landscape modification to explain post-deglaciation landscape evolution. Ballantyne himself continued to investigate the nature and effects of deglacial inheritance, primarily through a remarkable programme that involved exposure dating of 31 catastrophic rock-slope failures in Scotland and Ireland to demonstrate that over 90% occurred within 5 ka after deglaciation, and more intriguingly to show that maximum rockslide activity coincided with the most period of most rapid glacio-isostatic uplift, suggesting that earlier ideas linking kinematic release to seismic activity are worth revisiting.

As the above account suggests, Ballantyne's research interests are difficult to encapsulate. His record of over 150 published papers (mostly as single or senior author) plus over 50 chapters in books and field guides includes a remarkable diversity of material, ranging from papers on orientation statistics, clast shape analysis and climatic gradients to experiments on patterned ground generation to recent reassessments of the dimensions and deglacial chronology of the last British-Irish Ice sheet.

Over many years he has served the QRA in a range of capacities, including as an ordinary committee member, convenor of the meetings committee, and co-organiser of the 1987 Field Meeting in Wester Ross, the 1991 Field Meeting on Skye and the 2007 Annual Discussion Meeting in St Andrews. He has also been a contributor to nine QRA Field Guides. In 2008 he gave the first Elsevier lecture at the Annual Discussion Meeting at the RGS in London. The quality

and originality of his research work has been recognized in several awards and prizes, including the Warwick Award of the BSG, the President's Medal of the RSGS, the Newbigin Prize of the RSGS, the Wiley Award of the BSG, the Saltire Science Medal in Earth Sciences and the Clough Medal in Earth Sciences. He was elected Fellow of the Royal Society of Edinburgh in 1996 and awarded the degree of DSc by St Andrews University in 2000. More recently Colin has been awarded the Coppock Medal of the RSGS and simultaneously elected as a Fellow of that society!

Stewart Campbell

Stewart attended the University College of Wales, Swansea as an undergraduate between 1976-1979, where he took First Class Honours in Geography. He then went on to research his PhD, again at Swansea, on the Quaternary stratigraphy and geomorphology of the Gower.

In 1983 Stewart began working full-time at Swansea University on contract to the Nature Conservancy Council's Geological Conservation Review Unit. During this time he produced a comprehensive assessment of a series of geomorphological/



Quaternary sites in Wales that culminated in 69 of them being recommended for scheduling as SSSI and provided all of the documentation necessary for the production of the NCC's Geological Conservation Review (GCR) Series. Stewart's work at this time included the establishment of a wide network of earth scientists (which still functions) to provide advice to NCC and Countryside Council for Wales staff on matters of site protection for Quaternary and geomorphological localities in Wales. Major written contributions were also made to the First International Conference on Geomorphology in 1985, when Stewart led field excursions to Snowdonia and Llŷn.

In 1987 Stewart moved to the Earth Science Division of the Chief Scientist's Directorate in Peterborough as a geomorphologist/Quaternary stratigrapher with the NCC, a job that required him to take on responsibilities for a whole range of geomorphological disciplines and sites in widely separated areas (including some 400 different localities in Wales and England). Whilst in this post he also completed the assessment of potential periglacial GCR sites in East Anglia and contributed to several GCR publications, including *The Quaternary of Wales* (1989), which he also edited (with D.Q. Bowen).

Stewart's expertise and wide experience of Quaternary sites allowed him to make a major contribution to the QRA's Field Meeting to North Wales in 1990, including writing and editing the field guide, leading parts of the field excursion and giving the introductory lecture. Indeed, throughout Stewart's career he has participated regularly in research and field-based expeditions/meetings, particularly those of the QRA. These have included West Cornwall

(1980), Wessex and the Isle of Wight (1987), East Anglia (1988), North Wales (1990), Nairn and the Beuly Firth (1990), Isle of Skye (1991), Mull (1993), South-West England (1996) and West Cornwall (1999).

In 1991 Stewart became the Senior Geomorphologist for CCW in Bangor, working as a Quaternary geomorphologist and stratigrapher. Initial responsibilities included setting up an HQ Earth Science branch and recruiting a variety of earth sciences and monitoring staff. In the absence of geologists during 1991 he had to provide advice on the whole range of earth science disciplines. Working at CCW Stewart held a number of roles (including Head of Earth Science) and, at the same time, took on the job of editing *Quaternary Newsletter* between 1996 and 2000. Notable achievements for Stewart included writing the first LGAP (Local Geodiversity Action Plan) for Wales (Anglesey), supporting the successful GeoMôn (Anglesey Geopark) bid for European Geopark & UNESCO Geopark status and being responsible for initiating and running CCW's Geomorphological Map project (jointly with Aberystwyth University).

After taking early retirement from CCW in early 2010, Stewart continued to work with CCW, Regionally Important Geodiversity Sites (RIGS) groups and the Association of Welsh RIGS Groups (AWRG) in taking forward the WAG-sponsored Wales-wide RIGS audit project. The principal output from this period was the completion of two RIGS reports: one dealing with Quaternary and historical RIGS on Anglesey and the other with igneous RIGS (mainly Palaeozoic and Palaeogene dyke sites) on the island, jointly with Rob Crossley of Fugro-Robertson Ltd. Stewart was also involved in the establishment of Geodiversity Wales, a national body supporting the promotion of geoconservation and geodiversity activities in Wales.

Currently Stewart is employed by the newly-formed environmental body, Natural Resources Wales, monitoring geological sites, providing technical advice and assisting with interpretation projects (including the Anglesey Geopark project). He was also involved with co-authoring the geoconservation chapter in the recently produced QRA volume *The History of The Quaternary Research Association* and writing a photographic field guide to the rocks and landscape of Anglesey (a joint project with Margaret Wood of Anglesey Geopark and Professor Brian Windley of Leicester University). He continues as managing Editor of *Earth Heritage* magazine and retains an active interest in Quaternary science, geomorphology and photography.

Charles Turner

Charles Turner went up to Cambridge with a Modern Languages Exhibition destined to read French and German (which he didn't want to do). In the face of great opposition from his tutor, a good deal of luck and brilliant help from the influential botanist and nature conservationist Franklyn Perring (for whom he had been doing plant recording for the original BSB Plant Atlas) he ended up studying botany, geology and invertebrate zoology with petrology/crystallography in his 2nd year (as he hated cutting up vertebrates long pickled in formalin). Charles eventually took Botany for his final year, but it might well have been



Geology after working in a gold mine in S Africa in the long vacation, but he had fallen under the spell of Harry Godwin even at that time.

Charles then began his PhD work with Richard West as supervisor looking first at late-glacial macrofossils from Hoxne with the intention of moving on to the Cromer Forest Bed. However, an assistant of Godwin's had examined a few samples from the Hoxnian parastratotype at Marks Tey a few years earlier and instead Charles embarked on a detailed study of that exceptional site. Harry Godwin remained a very big influence, encouraging him at every turn, taking an active interest in his work and also securing a further year's funding for him. This coincided with Frank Mitchell taking a year's sabbatical in Cambridge; he was Charles' external examiner and subsequently invited him to be his field assistant to study the raised beach deposits of the Channel islands. After finishing his PhD he then spent two years working for the British Museum (with Gale Sieveking) putting down boreholes around the Breckland, including at High Lodge – there are still small interglacial sites located by Charles that have never been studied further.

In 1968 Charles joined the Geography Department at Birkbeck as Lecturer in Biogeography, with a young Mr James Rose as Lecturer in Geomorphology. Charles' lab work was still done in Cambridge or at Imperial College through the good offices of Michael Kerney, with whom he worked on Holocene tufas in Kent.

In 1970 Charles applied for a job at the then proposed Open University, where he was offered the post of Staff Tutor in Science for the East Anglian Region, attached not to Biology but to Earth Sciences. There he worked under Professor Ian Gass, who was determined that this should become a top-notch research department built from scratch, which he achieved against all the odds!

The OU opened for business in January 1971, in the middle of a postal strike –tricky circumstances for an institution that relied so heavily on correspondence by mail. Not only had Charles interviewed and selected all the local tutors for the East Anglian Study Centres (and some London ones too) in chemistry, physics, biology and earth science but with two other staff tutor colleagues, he actually devised the science tutorial system for the regions. As well as travelling all round East Anglia Charles was commuting to Milton Keynes to join the course team writing the first Science Foundation course. The OU found bench fees for Charles to pursue research in the Subdepartment of Quaternary Research in Cambridge, where he also lectured. Meanwhile at the OU he was involved in writing courses both for Earth Sciences and Biology on the environment, ecology, evolution, geology and oceanography making sure to bring in such topics as pollen analysis, Quaternary history and classical palaeobotany. During this time Charles was also involved in NERC activities, serving both on the Geological Grants Committee and the Radiocarbon Laboratory Steering Committee in its early years.

On the closure of the Subdepartment of Quaternary Research Phil Gibbard suggested that Charles move with him to the Geography Department, where he continued to lecture on Quaternary stratigraphy and vegetational history even after retirement from the OU in 2005.

Over the years Charles' research has been marvellously varied – interglacial sites in East Anglia, Holocene tufas, collaboration with archaeologists in Spain, in Greece and most recently (and ongoing) research on the early Middle Pleistocene in Russia and in Germany encompassing a fair amount of polemical arguments about stratigraphy and vegetational history across Europe.

Charles' involvement with the QRA, or rather its forerunner the Quaternary Field Studies Group, began by running errands for his supervisor Richard West and for Richard Hey and involving Fred Shotton in preparation for the first field meeting of the new group in Birmingham.

Later, together with Jim Rose, Charles organized the QRA Annual Field Excursion based at Clacton in 1973 – not an easy task, as there was no obvious base available so they took over two adjacent guest houses, squeezing participants in like sardines. Later Charles was a QRA Committee Member (1978-1979) subsequently becoming Vice-President of the Association (1980-1982) and in the early years of the Association, he attended many, if not all, of the meetings.

With his fluent German, Charles became involved in visits of eminent German Quaternary scientists to East Anglia – laying the foundations for some long-lasting friendships. He also attended the first and subsequent meetings of a series of conferences and field trips in East Germany, organized by H.-D. Kahlke and based in Weimar, looking at such important sites as Voigtstedt, Süssenborn and Ehringsdorf etc. at a time when British scientists rare but which were enormously valuable scientifically. In due course Richard West and Charles ran two very successful excursions around East Anglia before and after the INQUA Congress in Birmingham. Charles was asked to take on the role of President of the INQUA Subcommission on European Quaternary Stratigraphy (“SEQS”), a post that he held for twice as long as the regulations suggested he should!

During his term of office, the SEQS held international meetings on the early Middle Pleistocene in Norwich and later in Rome, which resulted in the book *‘The early Middle Pleistocene in Europe’* and a volume of *Quaternary International*. The international esteem in which his work is held by many is recognized through the award, in 2012, of the prestigious Albrecht Penck Medal by the German Quaternary Association (*Deutsche Quartärvereinigung* (DEUQUA)).

QRA ¹⁴CHRONO AWARD

ARCTIC CARBON CYCLING IN AN UPLAND LAKE: PRELIMINARY RESULTS FROM DISKO ISLAND, WEST GREENLAND

Mark A. Stevenson

Background and rationale

Arctic lake sediments process and integrate autochthonous and allochthonous carbon, however the links between carbon storage and release are largely unknown (Cole *et al.*, 2007). Arctic lakes are known to process high amounts of carbon per unit area (Anderson *et al.*, 2009), however the drivers of carbon cycling at the landscape scale may be indirectly or directly related to Holocene climate variability, changes in glaciation or vegetation dynamics.

We expected during warmer periods (e.g. Holocene Thermal Maximum (HTM) and Medieval Climate Anomaly (MCA)) increased algal production, due to longer ice-free season and nutrient inputs from more developed terrestrial catchments, would lead to increased pigment production and higher carbon isotope ($\delta^{13}\text{C}$) values indicative of increased productivity. In cooler periods (e.g. Neoglacial and Little Ice Age (LIA)) we expected that terrestrial inputs would be reduced (fewer leaves) and so organic matter should primarily derive from autochthonous algae, with reduced algal production and suppressed productivity from shorter ice-free seasons and therefore lower $\delta^{13}\text{C}$ values. The specific aim of this QRA-¹⁴CHRONO Centre Radiocarbon Dating Award was therefore to assess the suitability of sediment core sequences from an upland lake on Disko Island, Greenland, to answer our hypotheses on lake Holocene carbon cycling, identify key climate periods and derive a draft chronology suitable for further radiocarbon dating.

Methodology and results

In April 2013 two overlapping Russian core sequences were taken at two separate locations, from an upland high elevation lake on Disko Island, west Greenland, near the deepest part of the lake (Disko 2, 575 m.a.s.l., N69°23.342', W53°24.085'). The sediment cores comprise bands of homogenous gyttja, sedimentary clays and bands of predominantly aquatic macrophytes. A bulk date from sequence 1 (DISKO 2 R1-D1 60-61 cm) yielded a date of $3,765 \pm 36$ ¹⁴C years (UBA-25170). Clear changes in algal pigments, C/N and $\delta^{13}\text{C}$ were

found in sequence 1, with an application currently in review at the NERC RFSC for further ^{14}C dates. A terrestrial macrofossil was identified in the deepest drive of the sequence 2 (DISKO 2 R2-D2 84-85 cm) and was dated to $2,951 \pm 37$ ^{14}C years (UBA-25168), with a paired bulk sample from the same depth (Disko 2 R2-D2 84-85 cm) which provided a result of $3,785 \pm 37$ ^{14}C years (UBA-25169). This offset of 834 ^{14}C years is significant and combined with non-directional pigment records from this core, we suggest that sequence 2 may be disturbed by a neighbouring scree escarpment, or the re-working of old carbon from glacial activity.

Significance

The preliminary radiocarbon dating results highlight the importance of initial low resolution radiocarbon studies, and to assess for reservoir effects where possible using terrestrial macrofossils to assess the feasibility of sediment sequences for further ^{14}C dating. The date on the un-disturbed sequence 1 suggests the core is likely to span $\sim 6,000$ ^{14}C years (sedimentation rate of ~ 52 ^{14}C years per cm). When further dating is completed on sequence 1, it will be possible to compare changes in algal pigments, C/N ratios, $\delta^{13}\text{C}$ and lipid biomarkers (*n*-alkanes, *n*-acids, *n*-alkenes) and with changes in regional proxies (e.g. Leng *et al.*, 2012; McGowan *et al.*, 2008) and calculate carbon accumulation rates for Disko 2 (e.g. Anderson *et al.*, 2009).

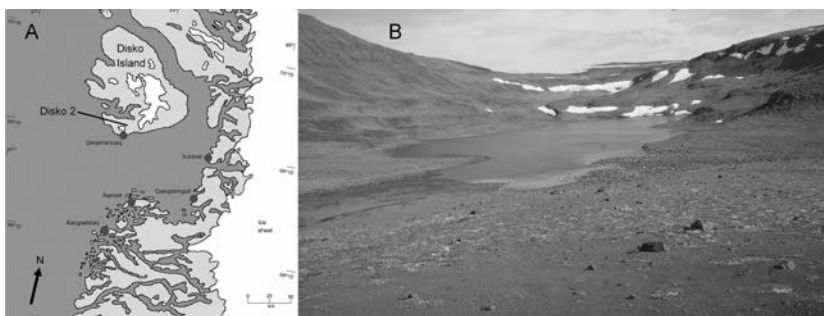


Figure 1. A. Location of lake Disko 2, on Disko Island, (west Greenland) and B. Image of lake Disko 2 during summer fieldwork (August 2013).

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NEW RESEARCHERS AWARD SCHEME

ASSESSING THE UTILITY OF MODERN ANALOGUE COLEOPTERAN (BEETLE) DATASETS IN QUANTIFYING HOLOCENE LANDSCAPE COVER AND USE

Background and Rationale

Over the past few decades there has been considerable discussion concerning the viability of palaeoenvironmental proxies to accurately reflect the structure of Holocene environments, particularly relating to landscape openness and spatial dynamics of the European ‘*Urwald*’ (the so-called ‘Vera debate’ cf. Vera, 2000; Svenning, 2002; Mitchell, 2005; Whitehouse and Smith, 2004, 2010; Smith *et al.*, 2010). This project aims to test and expand the approach taken by Smith *et al.* (2010), which used a modern analogue technique to interpret closed and open-canopy woodland environments, utilising Coleopteran datasets and other sub-fossil proxies. This approach will facilitate detection of landscape ‘openness’ within the Holocene period by providing a further quantitative methodology through which to assess the character of ancient landscapes.

Within any given ecological community, the species within are subject to a stochastic and continuous flux of colonisations and extinctions and as such are not considered a ‘settled matrix’ (Putman, 1994; Morin, 2011). This makes comparisons between ancient and modern communities as well as geographically distinct assemblages, at a simple species presence and abundance level difficult to quantify. Although species membership is variable between ancient and modern communities, there remain, however, some general patterns within a community at a guild and/or functional level that are organised around the availability of resources within nearby habitats (Putman, 1994). For the purposes of palaeoecological study, the species exploiting these habitats can therefore be considered parallel at this guild / functional level, enabling comparisons to be drawn across habitats.

The New Researchers Award Scheme facilitated travel to and expenses associated with the fieldwork in the Haanja National Park, Estonia (Fig. 1). The National Park is covered extensively with a Pine-Spruce-Birch nemo-boreal forest community and is notable for the significant amount of dead wood present on the forest floor (c. 13m³/ha; RMK, 2012) – this makes the area highly suitable for analysis since it potentially mimics the density of long-term deadwood found in many Holocene wildwoods (Whitehouse, 2006) and the coniferous forests found in the boreal Holocene period.



Figure 1. Location of Haanja National Park, Estonia

Results

Six forest hollows were visited in the Haanja National Park in summer 2012, from which two – five samples of ~5-7 litres were obtained for the extraction of their Coleopterous sclerites (and subsampled for palynomorphs). Four of six sites analyzed to date from Haanja produced an abundance of Coleopteran sub-fossils; overall 267 taxa were identified with an average minimum number of individual (MNI) of 727 at each location. For each site the surrounding landscape was mapped from satellite imagery within ArcGIS at buffers of 500m and 1000m (Fig. 2). This landscape was broken into four units (Fig. 2) from

which approximated areal coverage of the landscape units was deduced within ArcGIS. The landscape units were chosen to assess canopy cover and for ease of identification from available satellite imagery. Following identification and quantification of the taxa present within each assemblage, the functional group proportions for each site were calculated.

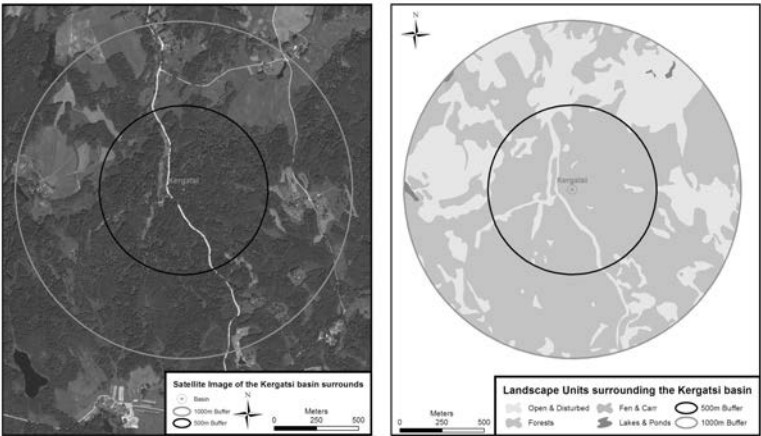


Figure 2. Satellite image and landscape units surrounding the ‘Kergatsi’ basin

Below are the results from the one forest hollow in Haanja pictured above (Fig. 2) revealing the dominance of forest cover within 500m, at 89%, being reduced to 68% within 1000m (Table 1). The results for the analysis of the coleopteran functional groups (Table 2) highlights the notably large and consistent presence of the ‘Woods and Trees’ (WT) group in each, as could be expected from a densely wooded landscape.

Table 1. Landscape unit coverage at 500m and 1000m limits from Kergatsi basin. Aquatic = Open water bodies (e.g. lakes and rivers); Fen = areas of open fen or marshland; Forest = densely forested areas (e.g. woods, plantations); Open = area of open or disturbed land (e.g. agricultural, pastoral, meadow, built land).

Kergatsi	Aquatic @ 500m	Fen @ 500m	Open @ 500m	Forest @ 500m	Aquatic @ 1000m	Fen @ 1000m	Open @ 1000m	Forest @ 1000m
M ²	0	0	85481	695742	8311	3882	976520	
% (0 d.p.)	0	0	11	89	0	0	31	68

Table 2. Terrestrial Functional Group proportions (%MNI) within beetle assemblages from the 5 Kergatsi basin samples. (DUNG = ‘Dung’, ELW = ‘Edge of, or light, Woodland’; FM = ‘Foul Material’; MA = ‘Marsh & Aquatic plants; MFC = ‘Marsh, Fen and Carr’, OD = ‘Open & Disturbed ground’; WT = ‘Woodland & Trees’.)

	DUNG	ELW	FM	MA	MFC	OD	R	WT
HK1	8	5	28	3	2	6	5	44
HK2	2	5	18	14	14	9	2	38
HK3	0	16	20	0	10	27	0	27
HK4	1	11	25	5	11	7	0	41
HK5	0	7	25	5	9	0	0	55

Significance

The results from one forested area alone is not sufficient for interpreting the effectiveness of Coleoptera in quantifying landscape cover. On top of the four sites visited in Haanja another 15 sites with varying forest cover / ‘openness’ have been analysed for this purpose, and includes pasture woodland, open parkland and wetland areas from the UK. The addition of further ‘functional tiers’ including information for each species, or taxon, based on their level of synanthropy and more detailed habitat preference allows for analyses beyond land cover alone. Early results from the combined modern analogue datasets are promising, with functional group dynamics corresponding to a number of landscape characteristics, including local landscape cover / ‘openness’. Re-visiting appropriate palaeo-sites with available Coleopterous assemblages on a comparative basis is ongoing.

Acknowledgements

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ABRUPT CLIMATE CHANGE AND AGRICULTURAL RESILIENCE: STABLE ISOTOPE ANALYSES OF CROP WATER STRESS AT HARAPPA, PAKISTAN

Background and Rationale

The impact of climate events on past societies has long been a source of speculation and debate. This study focuses on one of the lesser-known instances in which climate change has been linked to societal transformation: the decline of the Indus (or Harappan) Civilisation. Spread across the plains of northern South Asia, the Indus Civilisation thrived for much of the third millennium BC and at its height supported cities, extensive trade networks and sophisticated crafts. Yet from *ca.* 2000 BC, the evidence for these declines and by *ca.* 1500 BC, the Indus cities and material culture had largely disappeared (Wright, 2010).

This decline began at or shortly after a significant reduction in rainfall, for which there is mounting palaeoclimatic evidence (e.g. Dixit *et al.*, 2014; also Madella and Fuller, 2006). This shift appears to have been abrupt and was probably linked to the global so-called ‘4.2 ka climate event’ (Staubwasser and Weiss, 2006).

However, the connection between climatic and societal change in the Indus remains controversial. This study applies a novel technique, stable carbon isotope analysis of archaeobotanical crop remains, to directly test one of the arguments made to link the two: that climate change undermined the Indus Civilisation by reducing agricultural water supply. Stable carbon isotope analysis provides an ideal means of testing this because the stable carbon isotope ratio of C³ plants, such as wheat and barley, is closely related to water stress (Ferrio *et al.*, 2006). I have therefore applied this technique to over 100 wheat and barley grains from one of the Indus cities—the site of Harappa. These analyses, funded by the QRA New Researcher’s Award, aimed to test whether crops at Harappa became more water-stressed as rainfall declined *ca* 2200-2000 BC.

Methodology

Wheat and barley grains were selected from 13 archaeological contexts spanning *ca* 2800-1500 BC. Each grain was pre-treated in 0.5M HCl at 80°C for 60 minutes before analysis in an automated Costech elemental analyser, coupled in continuous-flow mode to a Finnigan MAT253 isotope-ratio- monitoring mass-spectrometer.

Results and Significance

The isotopic results from Harappa (Figure 1) show three key trends:

1. The average carbon isotope ratio ($\delta^{13}\text{C}$) of wheat does not change through time, implying stable water status;
2. The average $\delta^{13}\text{C}$ of barley decreases through time, implying improving water status;
3. Variability in $\delta^{13}\text{C}$ in both crops decreases through time, particularly after *ca* 2000 BC.

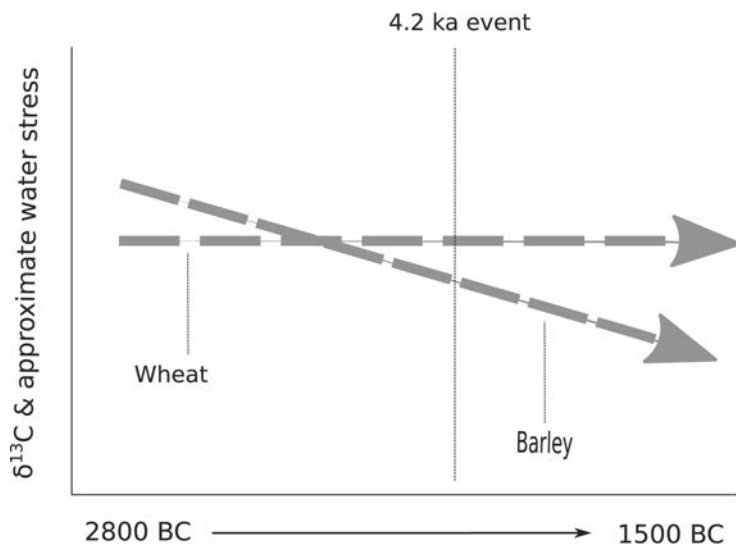


Figure 1. Approximate water stress in wheat and barley at Harappa, based on stable carbon isotope measurements ($\delta^{13}\text{C}$). Trends shown are indicative only, full details in Jones *et al.* in prep.

Clearly, these results do not support a simple model of climate change increasing crop water stress at Harappa. To the contrary, they imply that crop water supply remained stable or even increased and possibly became more reliable.

Harappa lies on one of the major tributaries of the Indus River and a possible explanation is that Harappa's access to riverine water allowed irrigation to buffer crops from the impacts of declining rainfall. While hydrological modelling suggests that river discharge as well as rainfall decreased *ca.* 2200-2000 BC (Wright *et al.*, 2008), riverine resources may nonetheless have provided Harappa with a relatively resilient agricultural water supply. Ongoing work at several smaller Indus Civilisation sites to the east, which do not have access to similar riverine resources, will provide a means of further exploring this hypothesis.

Overall, these results provide a thought-provoking new perspective on the question of how climate change may have affected the city of Harappa. More broadly, their suggestion that water management may have helped buffer crops from the impacts of rainfall decline highlights the need to recognise the possibility of adaptive responses in discourses about the impact of climate change on past societies. Finally, as the first archaeological application of this technique in South Asia, this study demonstrates the potential of archaeobotanical carbon isotope analysis to shed new light on the complex issues of climatic impacts, water management and agricultural resilience in the past.

Acknowledgements

This research was supported by the Quaternary Research Association New Research Worker's Award, which funded the isotopic analyses, and the Smuts Fund, which supported travel to collect the samples. The ERC Food Globalisation in Prehistory Project funded radiocarbon dates and the author's overall doctoral research is funded by the Rae and Edith Bennett Travelling Scholarship. The support of my supervisory team, Professor Martin Jones, Dr Tamsin O'Connell and Dr Cameron Petrie, is gratefully acknowledged, as is the assistance of Catherine Kneale and Louise Butterworth. Particular thanks are due to Dr Steve Weber, Washington State University, for allowing me to analyse the Harappa material.

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HOLOCENE TEPHROSTRATIGRAPHY OF THREE ALASKAN LAKES IN THE BROOKS RANGE AND EASTERN INTERIOR

Background and Rationale

The use of tephra as a means of independently dating and synchronizing records is becoming increasingly important in high resolution palaeoenvironmental research. In particular the use of cryptotephra that may be deposited and preserved many thousands of kilometres from the volcanic source (e.g. Jensen *et al.*, 2014) provide a means integrating both terrestrial and ocean records.

Alaskan volcanism is frequently explosive and visible ash layers cover much of southern Alaska and western Canada (e.g. Riehle, 1985), however despite this the limited use of cryptotephra remains largely confined to the south east of the state or reliant on incomplete rapid-assessment methods. Three Alaskan lakes: Lake 3 (67°4'33"N, 154°13'53"W) and Ruppert lake (67° 4'17"N, 154°14'39"W) in the Brooks Range, and Jan Lake (63°33'53"N, 143°55'1"W) in the Eastern Interior, were investigated for ash layers as part of the NERC funded *Lakes and the Arctic Carbon Cycle (LAC)* project, using continuous range finders and stepped density floatation.

Preliminary Results

Nine tephra layers were detected across the three lakes including five in Jan Lake and four previously unreported cryptotephra across the Brooks Range sites. Shards from six of these ash layers underwent electronmicroprobe (EMP) analysis at the University of Oxford in order to geochemically characterise the horizons and allow comparison between the each other and possible volcanic sources (the remaining layers will be analysed under the same conditions at a future date). With the exception of the youngest visible tephra preserved in Jan Lake (Fig. 1) which was largely formed of Dacite material, all ash layers were made up of predominately sub alkaline rhyolite shards, whilst encompassing a variety of shard morphologies. Initial results from the glass geochemistry, supported by shard morphology and age, allowed the correlation of the most abundant tephra layer between the Brooks Range sites. Further comparison of EMP data with previous studies indicates the ~3700 BP caldera forming eruption of Aniakchak as the most likely source, consistent with an initial northward fallout suggested by Begét *et al* (1992).

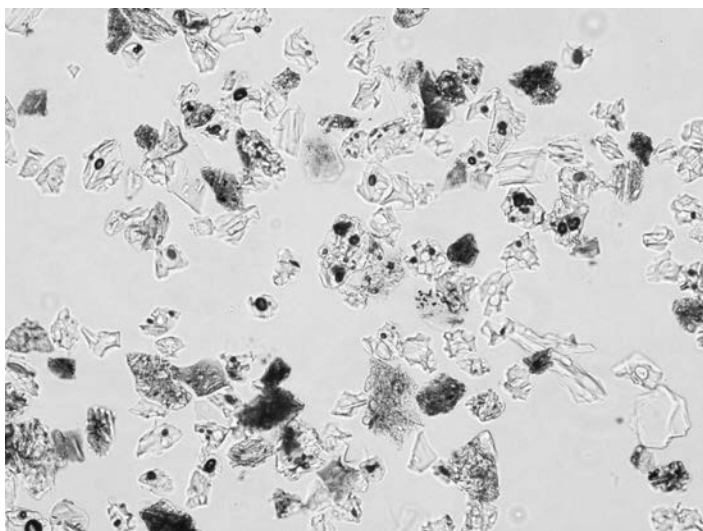


Figure 1. Glass shards from a visible layer in Jan Lake, Easter Interior Alaska.

Significance

EMP analysis of visible layers in the Eastern Interior will add to the limited available glass chemistry for Alaskan tephra. EMP data from this region is currently badly underrepresented in the literature, with comparative data sets often inaccessible or poorly integrated.

The first detection of cryptotephra in the Brooks Range demonstrates the potential for the delivery and preservation of tephra in this region during the Holocene. Importantly the correlation of tephra between sites suggests the ash may represent part of a more widely dispersed layer that could provide an important dating isochrone in a region where radiocarbon dating is often hampered by a lack of suitable organic material. Finally if the correlation between the Brooks Range tephra and the ~3700 BP Aniakchak eruption proves correct it will demonstrate a northward ash component along with the documented eastward transport (Pyne O'Donnell *et al.*, 2012).

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QUATERNARY RESEARCH FUND

(LACK OF) SEDIMENTARY EVIDENCE FOR THE LAST GLACIATION OF LUNDY ISLE

Introduction

Lundy Isle lies at a key position for understanding the last glaciation of the British Isles, as it is directly east of the Irish Sea palaeo-ice stream that extended to the Scilly Isles (Hiemstra *et al.*, 2006) and south of the reconstructed limit of ice extending into the Bristol Channel from Wales (e.g. Hiemstra *et al.*, 2009). It is surprising therefore to note that until recently Lundy Isle has received scant attention in terms of glacial geomorphology, with only brief speculative notes of possible glacial sediments and landforms in the north of the island reported by Mitchell (1968) and a related note from Taylor (1974).

A recent investigation by Rolfe *et al.* (2012) presents a geomorphological map and exposure age-dates from which it is suggested Lundy Isle was completely inundated by an ice sheet during the last glaciation. Exposure-age dates are used to suggest earlier glaciation of Lundy than elsewhere in South Wales or the Irish Sea basin (McCarroll *et al.*, 2010), and that the island was ice-free or beneath cold-based ice at the time of the maximum extent of the Irish Sea ice stream. This has major implications for understanding the geometry, dynamics and timing of ice sheet development during the last glaciation in the south-western British Isles. Rolfe *et al.* (2012) base their interpretation of glaciation of Lundy primarily on the description of glacial erosional landforms, glacially-transported boulders and meltwater channels. Small sheets of diamicton were noted at locations across the island, but were not described or interpreted in their work.

The aim of this project was to describe and sample the diamictons identified by Rolfe *et al.* (2012) to extract sedimentological and micro-scale (thin section, X-ray CT) information, assuming that at least some of the diamictons are glacial. Fieldwork was undertaken in September 2014 as a reconnaissance trip to explore the future potential for further glacial research on Lundy Isle.

Preliminary Findings

This project sought to extend our understanding of the last glaciation of Lundy Isle, adding to the context already provided by Rolfe *et al.* (2012). All the locations of diamictons identified in their work were visited and explored in detail, with the exception of the diamicton in the vicinity of St Helena's Church, which as consecrated ground was not excavated or augered at this preliminary stage of research (Figure 1).

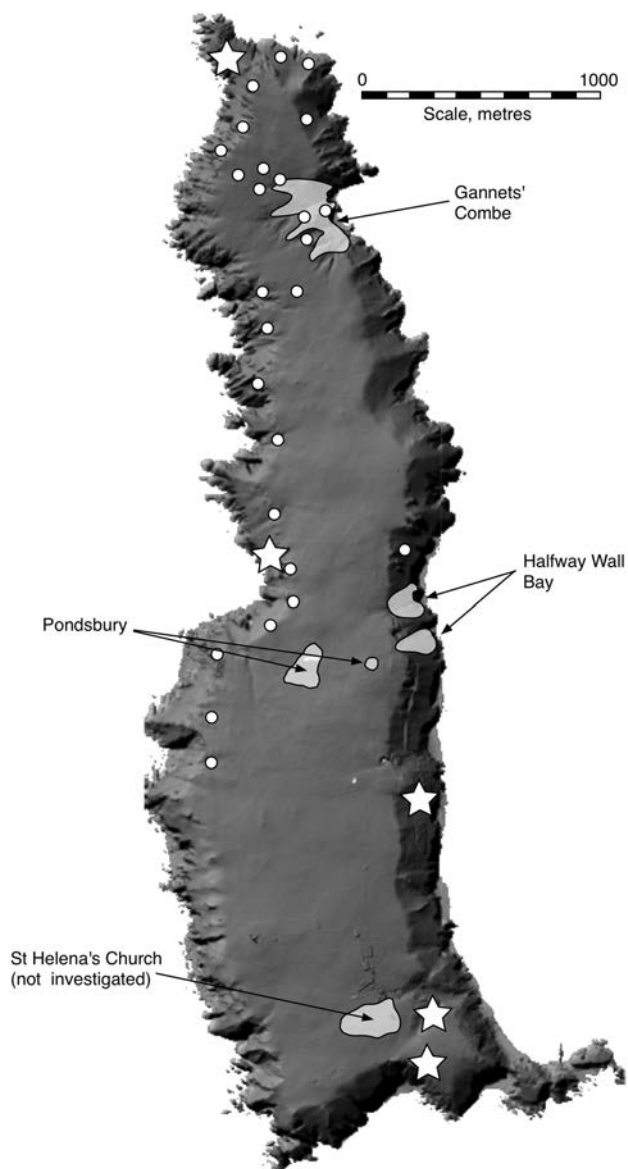


Figure 1. Location of sediment exposures visited and described on Lundy Isle, as well as the position of mapped sheets of diamicton reported by Rolfe *et al.* (2012). The white stars identify the locations of small sediment sections comprising grass over bedrock, and the small white dots identify locations of observations of geomorphological features on the island. Digital Surface Model © Environmental Agency.

Rolfe *et al.* (2012) identify two patches of diamicton at Pondsbury, near the centre of the island (Figure 1): despite considerable examination, at neither location was any diamicton found. Rather, at both sites there was a very thin regolith and soil overlying *in situ* granite bedrock (Figure 2a). Similar observations were made at Gannets' Combe, where Rolfe *et al.* (2012) report a sheet of diamicton located within a dendritic network of channels and gullies interpreted as subglacial meltwater channels. Finally, to the east of Pondsbury, two wedges of diamicton were observed to comprise vegetated talus slopes, common on the coastal cliffs of Lundy, although these were not mapped as such by Rolfe *et al.* (2012).

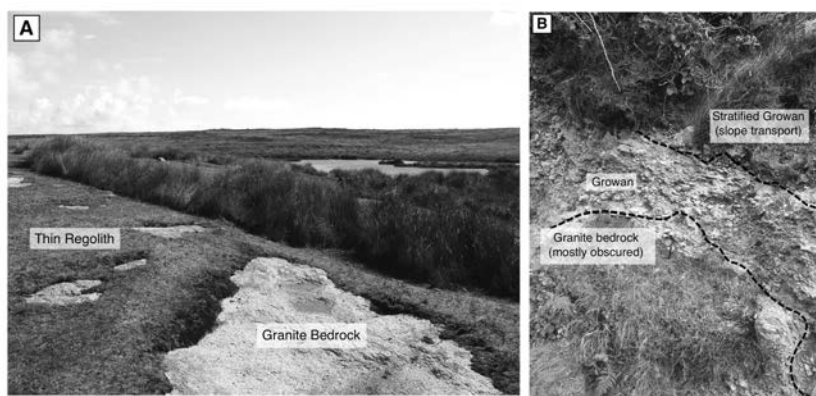


Figure 2. Examples of sediment exposures on Lundy Isle. A: Vegetation and thin soil overlying granite bedrock in the vicinity of Pondsbury lake, identified as having a significant cover of diamicton by Rolfe *et al.* (2012). B: Conformable sequence of granite bedrock, overlain by gruss and a slope mantle, Quarry Pond.

As a consequence of these highly unexpected outcomes, the original aim of this project could not be met, and therefore no sampling was undertaken for thin section or CT analysis. However, further investigations were undertaken to verify and evaluate the other mapped evidence reported in support of a glacial geomorphological imprint on Lundy Isle. All sites identified on the geomorphological map by Rolfe *et al.* (2012) were visited, as well as sites noted by Mitchell (1968), Taylor (1974) and additional locations not previously reported (Figure 1). Whilst the features recorded and described (bedrock outcrops, ‘ice-moulded’ bedrock and ‘whalebacks’, grooves, meltwater channels) in previous studies were all located, our provisional interpretation is that the glacial explanations for the origins of such features are not consistent with the evidence observed, and that in all cases, *in situ* weathering of the granite bedrock is a more robust interpretation of features described. In

addition, sediment exposures identified across the island all record the the *in situ* weathering of granite, producing gruss (Figure 2b), which locally has been modified by transport down-slope. Consequently, we favour the alternative view expressed briefly by Rolfe *et al.* (2012) that the geomorphology of Lundy reflects processes of granite weathering. Further, we conclude that there is no direct evidence to support that any of Lundy Isle was influenced by Late Quaternary glaciation.

These preliminary conclusions have significance in the wider context of the last glaciation of the Irish Sea basin, and would suggest that Lundy Isle and the Bristol Channel area remained ice free through the period leading up to and including the LGM. The dates reported by Rolfe *et al.* (2012) are very similar to those obtained from tors on Dartmoor (Gunnell *et al.*, 2013), and would suggest that the ages on Lundy reflect the nature and rate of cold-climate weathering of granite during the last glacial cycle, rather than a complex regional ice-sheet history.

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HOLOCENE TEPHROCHRONOLOGY IN SOUTHERN PATAGONIA: DEVELOPMENT AND INCORPORATION OF A CRYPTOTEPHRA FRAMEWORK

Background and rationale

Current understanding of the tephrochronological framework of southern South America stems largely from the examination of visible tephra horizons in a range of sedimentary archives, varying in thickness from 1 to >40 cm (Kilian *et al.*, 2003; Stern, 2008; Daga *et al.*, 2010; Watt *et al.*, 2011; Fontijn *et al.*, 2014). Despite the potential demonstrated by cryptotephrochronology (i.e. using microscopic horizons for dating purposes) in the peatlands of Europe (Pilcher and Hall, 1996; Pilcher *et al.*, 1996; Hall and Pilcher, 2002; van den Bogaard and Schmincke, 2002; Davies *et al.*, 2005; Wastegård, 2005) and, increasingly, North America (Payne *et al.*, 2008; Pyne-O'Donnell *et al.*, 2012), the technique has yet to be widely applied in southern South America. Raised ombrotrophic peatlands, as well as providing potentially high-resolution, multi-proxy records of past climatic change (e.g. Amesbury *et al.*, 2012; but see Swindles *et al.*, 2012) and carbon dynamics (e.g. Charman *et al.*, 2013), are ideal systems in which to develop cryptotephrochronologies, as their vegetated surfaces are effective at trapping tephra shards, alteration of shard geochemistry is usually limited and shard extraction is relatively simple (Payne *et al.*, 2008; Swindles *et al.*, 2010). Tephrochronology can also provide important absolute links between palaeoclimatic archives.

Methods

As part of the PATAGON^{*} and PARAD[†] projects, peat cores were collected from raised ombrotrophic peat bogs across southern Chile and Tierra del Fuego (53–55°S) in the austral summers of 2012 and 2013.

Identification of cryptotephra horizons followed standard ashing protocols (Hall and Pilcher, 2002; Swindles *et al.*, 2010). Although it has been shown that no geochemical difference is observed following electron probe microanalysis (EPMA) of shards isolated from the organic peat matrix by acid digestion and density separation in the Icelandic rhyolitic tephra, Hekla 4, the effects of acid digestion on a broader range of geochemistries remains uncertain (Roland *et al.*, in press). As little tephra geochemistry data is available from southern Patagonia, visible and cryptotephra glass shards were then isolated and concentrated using the density separation technique to guarantee preservation of the original geochemical composition.

Standard density separation methodology was followed (Blockley *et al.*, 2005) with slight modifications (S.D.F. Pyne-O'Donnell, pers. comm.). Sample material was sieved between 125 and 15 µm. Additional stirring was introduced

between floats at the cleaning stage to encourage disaggregation of shards from the fibrous peat. This was repeated five times before the sample was subjected to three additional cleaning floats to fully remove organic components and maximize shard extraction.

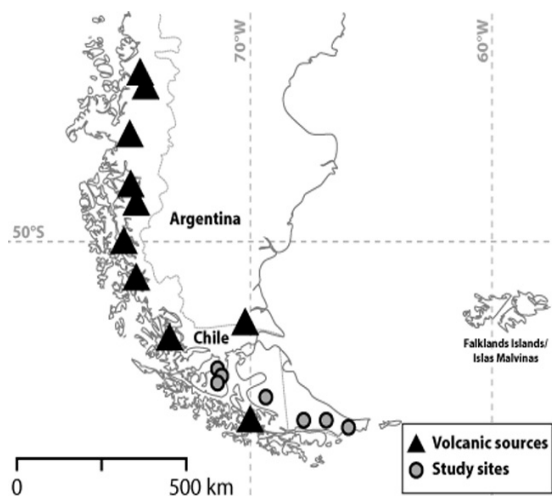


Figure 1. The location of the study sites in relation to the main volcanic sources in southern Patagonia.

Samples were mounted in an epoxy resin then ground and polished to expose tephra shards. Subsequent geochemical analysis using EPMA was undertaken at the School of Geosciences, Edinburgh University, using a Cameca SX100 electron probe micro-analyser. Analytical conditions were set to minimize sodium migration while maintaining an acceptable level of precision (Hayward, 2011). Geochemical analytical costs were funded in part by a contribution from the Quaternary Research Fund.

Results and Discussion

Of the visible and cryptotephra horizons identified and analysed here the majority were of rhyolitic composition. However, smaller numbers of basaltic trachyandesitic, basaltic andesitic, trachyandesitic, andesitic, trachydacitic and dacitic shards were also present. Such geochemical compositions are consistent other evidence from the region (cf. Fontijn *et al.*, 2014).

Shards from several horizons had particularly wide geochemical distributions. This could indicate that the concentration of tephra at this depth, as witnessed in the original shard counts, was not the result of a discrete volcanic eruption but rather represents a reworking of a range volcanic material present in the

landscape possibly caused by increased windiness. This highlights the need for further research into the application of cryptotephrochronology in areas, such as southern Patagonia, where tephra are far more abundant and therefore available for reworking in the region's sedimentary deposits, than in other regions where peat-based tephrochronology was originally developed (e.g. NW Europe). The challenge here, as in many instances in palaeoenvironmental research, is to separate the signal from the noise.

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* PATAGON (Palaeoclimate reconstructions from Tierra del Fuego to detect land-ocean-atmosphere interactions) is a NERC-funded collaborative research project between the University of Aberdeen, University of Southampton, Swansea University and Plymouth University. For more information, please visit: <http://patagonproject.org>

† PARAD (Peat bog records of atmospheric dust flux) is an ANR-funded collaborative research project principally based at EcoLab (CNRS), Université de Toulouse, France. For more information, please visit: <http://anr.obs-mip.fr>

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